

Nematodes of Yellow Perch from Saginaw Bay, Lake Huron, with Emphasis on *Eustrongylides tubifex* (Dioctophymatidae) and *Philometra cylindracea* (Philometridae)

JENNIFER L. ROSINSKI,¹ PATRICK M. MUZZALL,^{1,3} AND ROBERT C. HAAS²

¹ Department of Zoology, Michigan State University, East Lansing, Michigan 48824 and

² Michigan Department of Natural Resources, Mt. Clemens Fisheries Station, Mt. Clemens, Michigan 48045

ABSTRACT: Two hundred forty yellow perch, *Perca flavescens* (Mitchill), collected from 4 locations in Saginaw Bay, Lake Huron, Michigan, in May and September/October 1992, were examined for nematodes. A total of 6 nematode species (*Eustrongylides tubifex* (Nitzsch, 1819) Jägerskiöld, 1909; *Philometra cylindracea* (Ward and Magath, 1917) Van Cleave and Mueller, 1934; *Dichelyne cotylophora* (Ward and Magath, 1917) Petter, 1974; *Raphidascaris* sp. Railliet and Henry, 1915; *Camallanus oxycephalus* Ward and Magath, 1917; and an unidentified gravid female nematode) infected yellow perch; *E. tubifex* and *P. cylindracea* were most common. Prevalences and mean intensities varied with month and location of yellow perch collection. Yellow perch from The Black Hole, which is the most eutrophic location, had a significantly higher mean intensity of *E. tubifex* than fish from other locations. Prevalence and intensity of *E. tubifex* increased in larger and older yellow perch. The mean intensity of *P. cylindracea* did not vary significantly with location. Occurrence of *E. tubifex* and *P. cylindracea* is influenced by the distribution of intermediate and/or paratenic hosts, the feeding habits of the perch, and the life histories of the nematodes.

KEY WORDS: nematodes, *Eustrongylides tubifex*, *Philometra cylindracea*, yellow perch, *Perca flavescens*, Saginaw Bay, Lake Huron.

Bangham (1955) and Dectiar et al. (1988) surveyed the parasite fauna of Lake Huron fishes including yellow perch, *Perca flavescens*, but their studies did not include Saginaw Bay. They found 5 and 4 species of nematodes in yellow perch, respectively. Except for Allison* (1966) and Salz (1989), who reported only on the occurrence of *Eustrongylides tubifex*, investigations of the parasitic nematode fauna of yellow perch from Saginaw Bay do not exist. Yellow perch are the most important hosts of *E. tubifex* in Lakes Huron and Erie (Allison, 1966; Cooper et al., 1978; Crites, 1982). It is also thought that reduced yellow perch growth and fish mortality may result from infection with *E. tubifex* and *Philometra cylindracea* (see Allison, 1966; Crites, 1982; Salz, 1989). This paper reports on the occurrence and distribution of *E. tubifex* and *P. cylindracea* in yellow perch from 4 locations in Saginaw Bay.

Materials and Methods

A total of 240 yellow perch was collected by otter trawl in May and September/October 1992 from 4 lo-

cations in inner Saginaw Bay, Lake Huron, Michigan. Saginaw Bay is the southwestern extension of Lake Huron located in east-central Michigan. The inner bay is enriched with domestic, agricultural, and industrial inputs from the Saginaw River (Michigan Department of Natural Resources, 1988). It is a large, shallow, eutrophic bay that serves as a major fish spawning and nursery area and as a refuge and food source for many birds (Dolan et al., 1986; Michigan Department of Natural Resources, 1988).

The 4 collection locations (latitude, longitude/mean depth [m]) in the bay were The Black Hole (43°48'00", 83°50'00"/7.5), North Island (43°53'00", 83°26'00"/4.6), Au Gres (44°00'00", 83°40'30"/10.1), and Fish Point (43°43'00", 83°33'30"/5.9). The Black Hole is closest to the mouth of the Saginaw River, making it the most eutrophic location. Because of their close vicinity to the outer bay, North Island and Au Gres exhibit higher water quality and well mixed outer bay characteristics. Fish Point has less organic sediments and is less eutrophic than The Black Hole (Salz 1989).

Yellow perch were frozen in the field. Thirty yellow perch from each location in each month were measured (total length in millimeters) and sexed at necropsy. Scale samples were taken from the left side below the lateral line near the pectoral fin of each fish for age determination. Eyes, gonads, kidneys, spleen, liver, gall bladder, esophagus, gastrointestinal tract, heart, body cavity, and right or left side of musculature were examined. Nematodes were preserved in 70% alcohol and later cleared in glycerin for identification. The September/October collections are referred to as September.

The terms prevalence and mean intensity follow the definitions of Margolis et al. (1982). Mean intensities

³ Corresponding author.

* Allison (1966) identified the nematode as *Philometra cylindracea*, but it is now known that the nematode he studied was *Eustrongylides tubifex* (R. Haas, Michigan Department of Natural Resources, pers. comm.).

Table 1. Prevalence and mean intensity of *Eustrongylides tubifex* and *Philometra cylindracea* in 240 yellow perch from Saginaw Bay, Lake Huron, 1992. Thirty fish in each month from each location were examined.

Location	Month	<i>Eustrongylides tubifex</i>		<i>Philometra cylindracea</i>	
		No. infected (%)	Mean intensity \pm SD (maximum)	No. infected (%)	Mean intensity \pm SD (maximum)
The Black Hole	May	26 (87)	6.0 \pm 4.9 (13)	9 (30)	1.0 (1)
	September	27 (90)	12.7 \pm 10.6 (48)	3 (10)	1.3 \pm 0.6 (2)
North Island	May	27 (90)	4.3 \pm 4.4 (20)	8 (27)	1.4 \pm 0.5 (2)
	September	21 (70)	4.5 \pm 3.1 (11)	11 (37)	4.4 \pm 5.7 (19)
Au Gres	May	23 (77)	4.8 \pm 6.4 (32)	9 (30)	1.1 \pm 0.3 (2)
	September	26 (87)	5.9 \pm 4.6 (18)	3 (10)	1.0 (1)
Fish Point	May	25 (83)	5.3 \pm 3.9 (17)	10 (33)	1.4 \pm 0.7 (3)
	September	18 (60)	5.7 \pm 5.0 (19)	4 (13)	2.3 \pm 1.5 (4)

are followed by \pm standard deviation (SD). Chi-square analyses were performed to determine whether the prevalence of fish infected with a nematode species was independent of month, location, and fish age, length, or sex. Fish length classes were arbitrarily established. Intensity data for each species were rank transformed (Potvin and Roff, 1993) to correct for nonnormality. Multiway analysis of variance (ANOVA) was used to examine the effects of fish size and age, month, and location on nematode intensity. This determined whether individual factors had a significant effect on mean intensity of each nematode species and also whether interaction of factors significantly affected mean intensity. All tests were performed at a significance level of $P \leq 0.05$.

Voucher specimens of the following nematodes (U.S. National Parasite (USNPC) Collection No.) have been deposited at the USNPC: *Eustrongylides tubifex* (86802), *Philometra cylindracea* (86803), *Dichelyne cotylophora* (86804), and *Camallanus oxycephalus* (86805).

Results

Nematodes: general

A total of 6 nematode species was found in yellow perch from Saginaw Bay in 1992: *Eustrongylides tubifex*, *Philometra cylindracea*, *Dichelyne cotylophora*, *Raphidascaris* sp., *Camallanus oxycephalus*, and a single, gravid female nematode occurred in the wall of the intestine; the latter was not identified because the anterior end was missing. Of the 240 yellow perch examined, 215 (90%) were infected with at least 1 nematode, and 50 (21%) were concurrently infected with *E. tubifex* and *P. cylindracea*. The numbers (percentages) of fish infected with at least 1 nematode at each location in May and September, respectively, were The Black Hole, 28 (93%) and 28 (93%); North Island, 29 (97%) and 25 (83%); Au Gres, 28 (93%) and 28 (93%); and Fish Point, 27 (90%) and 22 (73%). No sig-

nificant difference in prevalence or mean intensity of each nematode species was found between male and female perch.

Eustrongylides tubifex

Third- and fourth-stage larvae were found encapsulated and free in the mesentery, muscles, liver, and gonads and free in the body cavity of perch. Capsules were somewhat round and flattened, yellow-pink or yellow-white. When dissected, a cloudy exudate was released with the larval nematode. Out of 1,208 *E. tubifex* recovered, 127 (11%) were unencapsulated.

Prevalence of *E. tubifex* did not vary significantly with month (chi-square = 2.1; df = 1) or location (chi-square = 5.4; df = 3) (Table 1). Although mean intensity of *E. tubifex* did not vary significantly between months (ANOVA $F = 2.4$; df = 1, 145), it was consistently higher in fish collected in September (Table 1). Perch from The Black Hole had a significantly higher mean intensity (Fig. 1) than the other 3 locations (ANOVA $F = 5.0$; df = 3, 145). Mean intensity of *E. tubifex* in fish from the other locations did not significantly differ.

A significant difference in mean intensity of *E. tubifex* was detected in perch of different age classes (ANOVA $F = 7.5$; df = 10, 228). Age 0 perch were uninfected, and a trend of increasing mean intensity with host age was apparent (Fig. 2). A significant difference in mean intensity of *E. tubifex* among fish length classes was also found (ANOVA $F = 5.5$; df = 10, 282). Fish less than 100 mm in length had a significantly lower mean intensity than other length classes (Fig. 3). Intensity of *E. tubifex* increased with increasing fish length in classes 110 mm

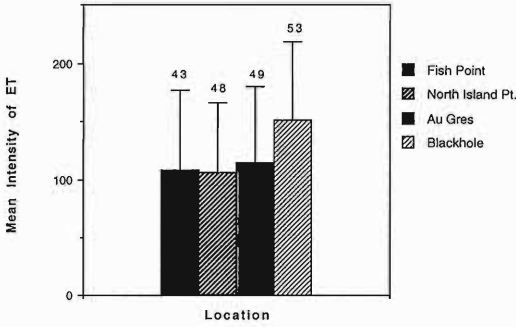


Figure 1. Mean intensity of *Eustrongylides tubifex* (ET) in yellow perch from 4 locations in inner Saginaw Bay, Lake Huron, 1992. Intensity data were rank transformed. Bars represent \pm SD. Number of infected fish is indicated above each location.

and larger. There was no significant difference in fish classes 100–139 mm or between 140 mm and larger.

Philometra cylindracea

Mature and gravid but not larvigerous *P. cylindracea* were found free in the body cavity, testes, mesentery, and heart of perch. There were no significant differences in the prevalence of *P. cylindracea* between months or locations (chi-square = 13.4; df = 7) (Table 1), nor in mean intensity among months or locations in Saginaw Bay.

Fish in age classes 0 and 5 had significantly higher mean intensities of *P. cylindracea* than all other age classes (ANOVA $F = 2.0$; df = 10, 47) (Fig. 4). No significant difference in mean intensity of this nematode was detected in other age classes. There was no significant dif-

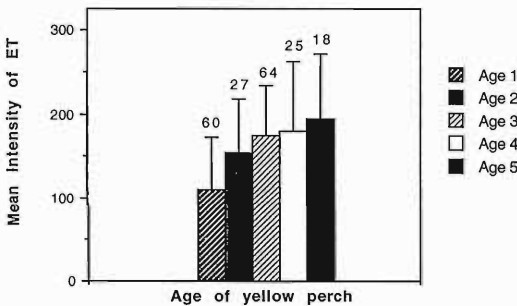


Figure 2. Mean intensity of *Eustrongylides tubifex* (ET) among age classes of yellow perch from Saginaw Bay, Lake Huron, 1992. Intensity data were rank-transformed. Bars represent \pm SD. Number of infected fish is indicated above each age class.

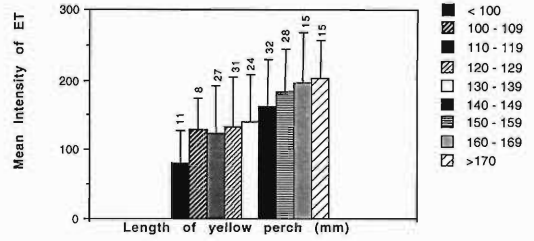


Figure 3. Mean intensity of *Eustrongylides tubifex* (ET) in yellow perch of different length (mm) classes. Intensity data were rank-transformed. Bars represent \pm SD. Number of infected fish is indicated above each length class.

ference in infection of yellow perch between length classes (ANOVA $F = 0.4$; df = 2, 35).

Other nematodes

Fourth-stage larval *D. cotylophora* were found in the stomach and small intestine of perch in May from Au Gres and North Island. Fish from The Black Hole and Fish Point were uninfected during this month. In September, gravid and a few fourth-stage larval *D. cotylophora* were found in the small intestine and stomach. Prevalence did not differ significantly between months but was significantly different among locations, being higher at Au Gres (chi-square = 29.6; df = 3). Mean intensities significantly differed between months (ANOVA $F = 133.2$; df = 1, 27) and among locations (ANOVA $F = 78.7$; df = 3, 27). There was no significant difference in either prevalence or mean intensity between Au Gres and North Island in May and no significant difference among locations in September. Differences in May data are due to uninfected fish at The Black Hole and Fish Point.

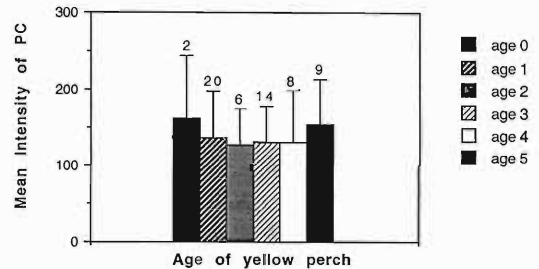


Figure 4. Mean intensity of *Philometra cylindracea* (PC) among age classes of yellow perch from Saginaw Bay, Lake Huron, 1992. Intensity data were rank-transformed. Bars represent \pm SD. Number of infected fish is indicated above each age class.

Gravid *C. oxycephalus* were found in the intestine in May at North Island only. Fourth-stage larval *Raphidascaris* sp. were found free in the liver and encapsulated in the liver, mesentery, and intestinal wall of perch from all locations. Prevalence was significantly higher in May than in September (chi-square = 34.9; df = 1), but there was no significant difference among locations (chi-square = 3.1; df = 3). Mean intensity did not significantly differ between months (ANOVA $F = 0.2$; $d = 1$, 56) or among locations (ANOVA $F = 0.6$; $df = 3$, 56).

Discussion

Based on the present study and studies by Bangham (1955) and Dechtiar et al. (1988), the nematode faunas of yellow perch from Saginaw Bay and Lake Huron proper are similar. Bangham (1955) found 5 nematode species in yellow perch from South Bay, Lake Huron proper, and Manitoulin Island. *Dichelyne corylophora* and *Philometra cylindracea* were common to both the present study and Bangham (1955). Dechtiar et al. (1988) found 4 nematode species in yellow perch from Lake Huron proper with *Eustrongylides tubifex*, *P. cylindracea*, and *D. (Cucullanellus) corylophora* common to both studies.

In Saginaw Bay, large amounts of organic sediments at The Black Hole support an abundance of benthic invertebrates. Schneider et al. (1969) found oligochaetes concentrated in this area, and Brinkhurst (1967) reported that areas around The Black Hole contained the highest percentages of tubificid oligochaetes in Saginaw Bay. Tubificid oligochaetes serve as the intermediate host for *Eustrongylides tubifex* (Karmanova, 1968; Measures, 1988a, b). In past studies, fish from localities with an abundance of tubificids had higher prevalences and mean intensities of *Eustrongylides* spp. because oligochaetes make up a larger portion of the fish diet (Kaeding, 1981; Crites, 1982; Hirshfield et al., 1983; Measures, 1988b). At The Black Hole location, the significantly higher mean intensity of *E. tubifex* can be attributed to the abundance of tubificid oligochaetes at that location. However, in the present study few oligochaetes were found in perch guts by one of us (J.L.R.), and Haas and Schaeffer (1992) did not report the presence of tubificids in perch stomachs. Perhaps tubificids break down quickly in perch guts (although it seems as though Haas and Schaeffer

accounted for this by immediately freezing fish with liquid nitrogen). It may also be possible that another invertebrate species serves as an intermediate or paratenic host for *E. tubifex* in Saginaw Bay. If another invertebrate is functioning in this role, results indicate that it is a pollution-tolerant organism that has a distribution similar to that of tubificids. The likely prospects are common food items in the diets of yellow perch from Saginaw Bay such as chironomid larvae and harpacticoid copepods.

Yellow perch exhibit age-size differences in feeding (Cooper et al., 1978; Crites, 1982; Haas and Schaeffer, 1992) that are reflected in the infection patterns of *E. tubifex* and *P. cylindracea* in different age-size classes of yellow perch. Larval *E. tubifex* have a long life span and can be transmitted from one fish to another before being transmitted to the definitive piscivorous bird host (Cooper et al., 1978). The increase in prevalence and mean intensity of *E. tubifex* with yellow perch age and length may reflect an increase in piscivory as well as an accumulation of worms over time. Piscivory by large yellow perch was observed in the present study as well as by Haas and Schaeffer (1992) and, at times, was extensive.

Feeding activity of yellow perch may also explain infection patterns with *P. cylindracea*. Yellow perch are the definitive hosts, and copepods act as intermediate hosts for *P. cylindracea* (Molnar and Fernando, 1975; Crites, 1982). Yellow perch are initially planktivores, and zooplankton remains an important food item in age classes 1 and 2 (Haas and Schaeffer, 1992) and maybe even throughout their lives (Crites, 1982). This is reflected in the significantly higher mean intensity of *P. cylindracea* in age class O fish. Age class 5 yellow perch also had a significantly higher mean intensity of *P. cylindracea*. This may indicate that large Saginaw Bay yellow perch consume an increased volume of copepods or that *P. cylindracea* can be transferred from one fish to another so that intensity increases with piscivory. Although transmission of *P. cylindracea* from one fish to another has not been demonstrated, it has been shown with *P. obturans* in pike, *Esox lucius*; perch, *Perca fluviatilis*; and rudd, *Sarcodinius erythrophthalmus* (see Molnar, 1976; Moravec and Dykova, 1978).

Philometra cylindracea has a 1-yr life cycle and becomes larvigerous in June or July in Lake

Erie (Crites 1982). This nematode declines rapidly in late June through July due to natural senescence of spent worms (Molnar and Fernando, 1975; Crites, 1982). The lack of larvigerous worms in the present study may be due to collection time prior to development of larvae within the nematodes. Abundance of *P. cylindracea* increases in September and early October as yellow perch ingest copepods infected with the new generation of larvae (Crites, 1982). The higher mean intensity, although not significant, of *P. cylindracea* in Saginaw Bay yellow perch from September may be directly related to the appearance of this new generation.

The high prevalence and mean intensity of *Eustrongylides tubifex* indicate that this nematode is well established in yellow perch from inner Saginaw Bay, Lake Huron. Although yellow perch have lower prevalence and mean intensity of *Philometra cylindracea*, it is also present in yellow perch throughout inner Saginaw Bay. Haas and Schaeffer (1992) reported that yellow perch in Saginaw Bay experience slow growth, energy depletion, and high natural mortality and suggested that this is probably due to the lack of benthic invertebrates on which to feed. Alternatively, *E. tubifex* and *P. cylindracea* may play a role in this reduced yellow perch growth and high mortality as suggested by Allison (1966), Crites (1982), and Salz (1989).

Acknowledgments

We thank J. Hodge and L. Shubel, Michigan Department of Natural Resources, Mount Clemens, Michigan, for collecting the yellow perch for this study and K. Nelson for technical assistance. K. Koster aged the yellow perch. This project was supported in part by the Department of Zoology, Michigan State University.

Literature Cited

- Allison, L. N. 1966. The redworm (*Philometra cylindracea*) of yellow perch (*Perca flavescens*) in Michigan waters of the Great Lakes. Michigan Department of Conservation Research and Development Report No. 53, Institute for Fisheries Report No. 1712.
- Bangham, R. V. 1955. Studies on fish parasites of Lake Huron and Manitoulin Island. American Midland Naturalist 53:184-194.
- Brinkhurst, R. O. 1967. The distribution of aquatic oligochaetes in Saginaw Bay, Lake Huron. Limnology and Oceanography 12:137-143.
- Cooper, C. L., J. L. Crites, and D. J. Sprinkle-Fast-
kie. 1978. Population biology and behavior of larval *Eustrongylides tubifex* (Nematoda: Dioctophymatida) in poikilothermous hosts. Journal of Parasitology 64:102-107.
- Crites, J. L. 1982. Impact of the nematode parasite *Eustrongylides tubifex* on yellow perch in Lake Erie. U.S. Department of Commerce Commercial Fisheries Research and Development Project No. 3-298-D.
- Dechtiar, A. O., J. J. Collins, and J. A. Reckahn. 1988. Survey of parasitic fauna of Lake Huron fishes, 1961 to 1971 In S. J. Nepszky, ed. Parasites of Fishes in the Canadian Waters of the Great Lakes. Great Lakes Fishery Commission Technical Report No. 51:19-48.
- Dolan, D. M., N. D. Warry, R. Rossman, and T. B. Reynoldson, eds. 1986. Lake Huron 1980 Intensive Survey: Summary Report, Report to the Surveillance Work Group. Windsor, Ontario. 133 pp.
- Haas, R. C., and J. S. Schaeffer. 1992. Predator-prey and competitive interactions among walleye, yellow perch, and other forage fishes in Saginaw Bay, Lake Huron. Michigan Department of Natural Resources, Fisheries Division. Research Report No. 1984.
- Hirshfield, M. F., R. P. Morin, and D. J. Hepner. 1983. Increased prevalence of larval *Eustrongylides* (Nematoda) in the mummichog, *Fundulus heteroclitus* (L.), from the discharge canal of a power plant in Chesapeake Bay. Journal of Fish Biology 23:136-142.
- Kaeding, L. R. 1981. Observations on *Eustrongylides* sp. infection of brown and rainbow trout in the Firehole River, Yellowstone National Park. Proceedings of the Helminthological Society of Washington 48:98-101.
- Karmanova, E. M. 1968. Dioctophymidea of Animals and Man and Diseases Caused by Them. Fundamentals of Nematology, Vol. 20. Academy of Science of the USSR. Translated and published for U.S. Department of Agriculture. Amerind Publishing, New Delhi, 1985. 383 pp.
- Margolis, L., G. W. Esch, J. C. Holmes, A. M. Kuris, and G. A. Schad. 1982. The use of ecological terms in parasitology. Journal of Parasitology 68:131-133.
- Measures, L. N. 1988a. The development of *Eustrongylides tubifex* (Nematoda: Dioctophymatoidea) in oligochaetes. Journal of Parasitology 74: 296-304.
- . 1988b. Epizootiology, pathology, and description of *Eustrongylides tubifex* (Nematoda: Dioctophymatoidea) in fish. Canadian Journal of Zoology 68:2212-2222.
- Michigan Department of Natural Resources. 1988. Michigan Department of Natural Resources Remedial Action Plan for Saginaw River and Saginaw Bay. Area of Concern. Michigan Department of Natural Resources, Great Lakes and Environmental Assessment Section. September 1988. 588 pp.
- Molnar, K. 1976. Data on the developmental cycle of *Philometra obturans* (Prenant, 1886) (Nematoda: Philometridae). Acta Veterinaria Academiae Scientiarum Hungaricae 26:183-188.

- , and C. H. Fernando. 1975. Morphology and development of *Philometra cylindracea* (Ward and Magath, 1916) (Nematoda: Philometridae). *Journal of Helminthology* 49:19–24.
- Moravec, F., and I. Dykova. 1978. On the biology of the nematode *Philometra obturans* (Prenant 1886) in the fishpond system of Macha Lake, Czechoslovakia. *Folia Parasitologica (Praha)* 25: 231–240.
- Potvin, C., and D. A. Roff. 1993. Distribution-free and robust statistical methods: viable alternatives to parametric statistics. *Ecology* 74:1617–1628.
- Salz, R. J. 1989. Factors influencing growth and survival of yellow perch from Saginaw Bay, Lake Huron. Michigan Department of Natural Resources, Fisheries Division, Fisheries Research Report No. 1964.
- Schneider, J. C., F. C. Hooper, and A. M. Beeton. 1969. The distribution and abundance of benthic fauna in Saginaw Bay, Lake Huron. *Proceedings of the 12th Conference of Great Lakes Research* 1969:80–90. International Association of Great Lakes Research.

1997 Meeting Schedule

15 January 1997	Armed Forces Institute of Pathology, Washington, D.C.
19 March 1997	Uniformed Services University of the Health Sciences, Bethesda, MD
3 May 1997	New Bolton Center, University of Pennsylvania, Kennett Square, PA
October 1997	To be Announced
November 1997	To be Announced